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HIGH

WIDE,

&amp; Windswept

By Bibi Booth, Richard Brook,  
Shelly Fischman, LouAnn  
Jacobson, Shelley Smith,  
and Mary Tisdale

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When film director John Ford made a movie about the American West, he would often include two superstars to ensure its success—John Wayne and the Colorado Plateau. Breathtakingly beautiful, the Colorado Plateau is one of the most intricate landscapes on Earth. Here, on a grand scale, erosion has carved arches, alcoves, canyons, domes, towers, temples, and hoodoos out of vividly colored rock. Magnificent vistas take in landscapes of salmon, purple, pink, and red stone, set in blazing contrast against intensely blue desert skies and dotted with dark green pinyon trees and soft sagebrush. It is a wild land, even today.

Sprawling across eastern Utah, western Colorado, northern Arizona, and northwestern New Mexico, the Colorado Plateau contains the most extensive blocks of undeveloped land in the West. It includes millions of hectares of federal land that meet the criteria for inclusion in the National Wilderness Preservation System. While five of the country's fastest-growing cities (Salt Lake City, Denver, Albuquerque, Phoenix, and Las Vegas) ring the plateau, its population is low and dispersed.

The prevailing colors are wonderfully deep and clear, changing and blending in varying intensity from hour to hour, day to day, season to season; throbbing, wavering, glowing, responding to every passing cloud or storm, a world of color in itself.

— John Muir, Steep Trails (1919)



JERRY SINTZ

The claretcup cactus, which stores water in its stems and roots, blankets the desert floor with flowers in spring.



JERRY SINTZ

As they roam the alpine tundra and pinyon-juniper life zones, bighorn sheep rely on more than 100 different plant species for food.

Globally unique, the Colorado Plateau combines colorful exposed geology, a rich mix of biotic environments, and numerous archaeological sites. Millions of visitors now come here to bike the slickrock, hike the twisting slot canyons, visit ruins, raft the whitewater, and find solitude in a place of rare natural beauty. Largely federal land, the Colorado Plateau boasts some of America's most popular parks and recreation areas. Utah's Grand Staircase-Escalante National Monument, designated in 1996 by Presidential Proclamation, is the plateau's most recent area to attract worldwide attention.

In this article, we explore the natural forces that have created such geologic drama, examine a few of the myriad plants and animals inhabiting the six life zones on the plateau, and provide an overview of the challenges faced by land managers seeking to care for the plateau's extraordinary life-forms and landforms.

## A Geologic Wonder

The Colorado Plateau is not just one plateau, but rather a huge area filled with stacked plateaus, surrounded by highlands to the north and lowlands to the south and west.

The oldest rocks on the plateau are more than 570 million years old. During the North American continent's turbulent detachment from Africa, Asia, and South America 300–400 million years ago and subsequent slow drift to its present location, the physiographic province that would later be known as the Colorado Plateau remained relatively undisturbed.

Over those hundreds of millions of years, warm shallow seas alternately

inundated and receded from the Colorado Plateau, and large quantities of sediment accumulated. The layers gradually sank under their own weight until heat and pressure hardened them into layers of sandstone, siltstone, shale, and limestone, several kilometers thick in places.

Then, between 80 and 40 million years ago, a violent uplift formed the Rocky Mountains, rainfall levels rose, and the Colorado River was created. These extraordinary mountain-building forces are reflected in the Colorado Plateau's domes, shallow basins, fractures, faults,

and long folds called reefs. Finally, around 10 million years ago, the entire western United States began to rise again as a result of tectonic compressional stresses; some portions eventually rose to altitudes of 5 km above sea level. The Colorado Plateau rose also—by more than 1.5 km—but remained structurally stable. Following this uplift, rivers began to carve deep, narrow canyons into the plateau's multilayered rock. Today, even as the plateau continues slowly and gently rising, erosion is simultaneously wearing it down.

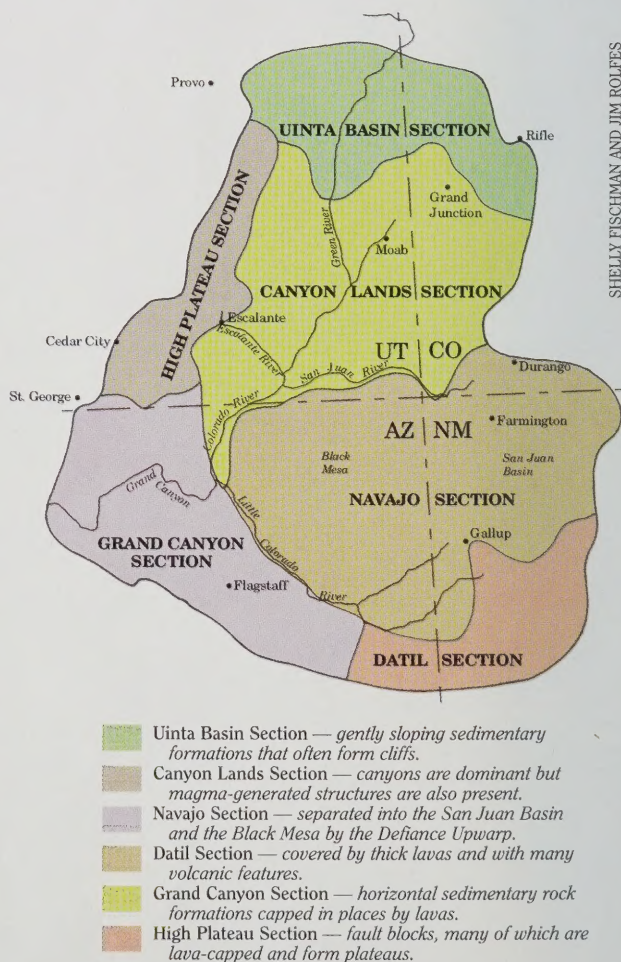
There is plentiful evidence of Cenozoic volcanic and magmatic activity within the plateau, including intrusions that have caused upwarps, tilting, and doming of strata, and extrusions in the form of volcanic landforms and lava-capped mountains. There are five major mountain ranges within the plateau, all formed by the action of magma that either gently upwarped sediments but never breached the surface, or was extruded from erupting volcanoes.

Within the plateau, rivers have incised thousands of kilometers of canyons, whose walls bear additional erosional features, such as alcoves, grottoes, windows, towers,

and honeycombs. Many of these canyons and gorges are remarkably deep and narrow, with ever-narrower side canyons branching off from main passages. For example, the Escalante River Canyon and its side canyons constitute a network of nearly 1,600 km. Yet the Escalante is itself only a side canyon—one of 50 major side canyon systems that are tributaries of the Colorado and Green Rivers.

Though wind and frost erosion contribute to the creation of some plateau landforms, direct erosion by water (rain, groundwater, runoff, and rivers) is the primary sculpting force for most of the unusual shapes. Generally, the odd forms result from differential erosion, which occurs when there are significant differences in relative hardness or cementation in the rock, especially where fracturing has occurred. For example, in the plateau, fractured sandstone is more susceptible to erosion by water than is intact limestone, which often comprises erosion-resistant caprock.

In addition to the thousands of mesas, buttes, domes, towers, monuments, temples, and spires carved by water, there is also a multitude of natural rock arches



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and bridges in the plateau, where wind (aeolian erosion) and ice have been contributory sculptors. At least five bridges have spans of more than 60 m.

Surface features also reveal the plateau's evolution. There are beautifully colored, lithified sand dunes; ripple marks frozen in rock; and whole forests of petrified trees. The area boasts hundreds of classic examples of geologic phenomena, often decorated in the brilliant reds, purples, and oranges of iron and other minerals.

## Ecological Diversity: Then and Now

The Colorado Plateau is indeed one of the world's premier natural showcases for Earth history. A canyon hiker can literally take a trip through time, descending through layers of rock representing progressively earlier geologic periods. Scattered through these layers are fossils such as tracks, shells, bones, leaves, and petrified wood.

At the Cleveland-Lloyd Dinosaur Quarry in northeastern Utah, scientists have uncovered 18,000 bones from 70 different dinosaurs and other species. Fossils of some of the earliest mammals, the size of small mice, have been found here in 225-million-year-old Triassic rock. The remains of large amphibians and armored, crocodile-like phytosaurs, some exceeding 9 m in length, have been found amidst petrified trees.

Dinosaurs from the Triassic to the Late Cretaceous (65 million years ago) left their traces on the plateau. Fossil sea life such as algal heads, marine reptiles, sharks, and squid-like creatures occur near ancient clam and oyster beds. Ancient insects, archaic saber-toothed mammals, and even mammoths, camels, and musk and shrub oxen once lived here.

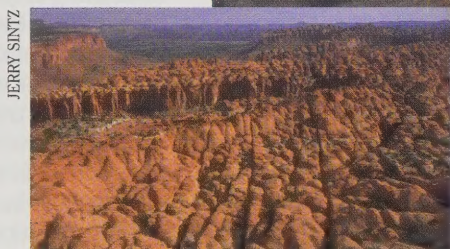
Today, great ecological diversity is the plateau's signature; high alpine tundra, boreal forests, salt deserts, and microbial crusts are each established here. Climate, elevation, and soil combine to create many microzones, which support an amazing range of plants and animals. Six of the seven North American life zones are represented on the plateau; only subtropical is absent.

The large expanses of exposed geologic strata, each with its own physical and



JERRY SINTZ

Water is the primary agent of erosion on the Colorado Plateau, sculpting dramatic surface landforms.



JERRY SINTZ

Variations in the properties of rock formations are reflected by different erosional patterns.

chemical characteristics, are the parent material for the diverse and

unusual soil types that support numerous endemic plants and their pollinators. Relict vegetation areas are extraordinary in number and many have existed here since the Pleistocene era. These relict areas provide a baseline against which to measure changes in plant community dynamics and natural cycles in areas impacted by human activity.

The variety of living creatures in this landscape is also exceptional. Some of the plateau's inhabitants are the collared lizard, jackrabbit, coyote, mule deer, bobcat, cougar, bighorn sheep, elk, quail, mourning dove, gray fox, and rattlesnake. Stellar jays, Clark's nutcrackers, red-tailed hawks, falcons, and a myriad of small migratory birds soar the plateau's azure skies. Rivers and small streams are the very lifeblood of plants and animals in the arid West. Cottonwood trees and hanging gardens fringe the waterways that thread throughout the plateau, hosting frogs, toads, snails, beavers, dragonflies, and fish.

TOPE ELEMENTARY SCHOOL



Microbiotic crusts, dark carpets of lichens, fungi, and algae, help to prevent erosion and act as seedbeds for desert plants.

JERRY SINTZ



Deeply incised, steep-walled canyons were formed by the increased velocity of rivers as the Colorado Plateau was uplifted.

Some animal species make use of the plateau's features in unique ways. The Mexican spotted owl prefers old-growth forests in its southern range, but here it is generally found in steep-walled rocky canyons below 2,400 m in elevation. Peregrine falcons are particularly plentiful on the plateau because the river canyons provide steep cliffs for nesting with abundant bird life (peregrine prey) in the riparian zone below. The steep talus slopes that skirt thousands of kilometers



JERRY SINTZ

A hiker squeezes through a narrow trail bounded by steep, wavy walls of amber sandstone.



JERRY SINTZ

Damp rockfaces host hanging gardens, miniature oases of lush vegetation.

of cliff face are habitat for bighorn sheep. By contrast, the same species in the Great Basin prefer isolated mountain ranges.

The plant life of the plateau is equally varied and remarkable, and the plateau is perhaps the richest floristic region in the Intermountain West. Once again, the plateau's array of geologic features, and the soils derived from these features, are responsible. Low-elevation rocky areas support desert shrubs such as saltbush and greasewood. Stands of pinyon pine and several species of juniper blanket much of the plateau. This "pygmy forest," as it is often termed, is interspersed with grasses, herbs, and shrubs such as sagebrush. At higher elevations, forests of ponderosa pine, Douglas fir, lodgepole pine, and aspen dominate. Numerous species of cactus grow throughout the plateau, and some of them are found nowhere else. Even documenting their presence is challenging; some lie dormant, desiccated and nearly invisible, until environmental conditions are just right. Recently, two new cactus species were discovered on the plateau.

The sandstone formations of the Colorado Plateau hold two particularly fascinating and unusual habitats: hanging gardens and potholes. Many plant species endemic to the Colorado Plateau are found along waterways in hanging gardens. These tiny areas of lush vegetation are the result of water's percolating through porous sandstone until it encounters a weaker horizon of rock. Generally, the water moves horizontally and surfaces at cliff faces. Here, it dampens the rockface and provides a foothold for plants to grow.

Potholes are depressions in the rock ranging in size from a teacup to a two-car garage. They form through chemical erosion along fault lines or persistent erosion by cascading water. The water in potholes is ephemeral. Potholes are filled by rainfall, which has no outlet except evaporation. In a sense, potholes are like

temporary aquariums in the rock; they support a remarkable miniature ecosystem that is virtually independent of other ecosystems.

The life-forms dependent upon potholes have strategies to cope with the unreliability of water. Creatures like toads and insects can simply leave when the water dries up. Many are adapted to reach maturity before leaving and reproduce during the next wet cycle. Some creatures produce a protective covering that conserves cell moisture. Snails have a hard shell, and they cover their operculum with a waxy sealant. Mites manufacture a fatty substance that is excreted in a shingle-like fashion. This covering slows water migration from their cells. Snails and mites move to the deepest sediment, where the temperature is coolest, and reduce their metabolic rate. Fairy shrimp eggs can tolerate a loss of 92 percent of their cell moisture and still be viable when the potholes refill. They use a sugar molecule (trehalose) to mimic the shape of a water molecule. The sugar molecule maintains the shape of the cells' components so they will function again when rehydrated.

## Management Challenges

The plateau's pattern of land administration complicates any approach to addressing land management issues. The complex patchwork of jurisdictions, missions, and management authorities includes: four states; a dozen Indian tribes; 34 counties; 225 communities; 26 national parks, monuments, national historic sites, and recreation areas; 15 national forests; and 15 Bureau of Land Management districts. Federal land comprises 55 percent of the plateau, Indian reservations 24 percent, and state and local governments 6 percent. Private lands amount to only 15 percent. Despite this mosaic of administration, collabora-

tion is the approach to meeting these management challenges.

The plateau's unique and magnificent landscape, studded with national parks and promoted worldwide, now attracts millions of visitors a year, many of them foreign. Incorporating tourism and its related businesses into the economy is a significant change. The traditional economy is built largely upon resource commodities such as timber, livestock forage, and minerals, and it continues to be important. Both traditional and visitor-supported businesses depend upon large tracts of federal land.

## Tourism

While local economies welcome tourism as a source of income, communities are scrambling to provide visitor services. Effects are felt ecosystem-wide. Small-town water, sanitation, emergency, and utility systems were not built to accommodate large transient populations lodging in new motels, eating in new restaurants, and getting lost or injured in unfamiliar back-country.

The impacts of tourism can be far-reaching. Many visitors concentrate in narrow canyon areas, trek over fragile microbial crusts, and damage riparian zones. Heavily used campsites are eroded and despoiled with litter and human waste. Riparian systems are under increasing demands as community water supplies. Wildlife is displaced or disturbed during critical breeding times. Native American sacred sites are subject to intrusion.

The plateau's archaeological sites (see the back of the accompanying foldout) are among the world's most numerous, spectacular, and well preserved, but visitation takes a heavy toll. Standing masonry walls of prehistoric ruins, artifact scatters, rock drawings, and rock shelters are easily damaged or destroyed by uninformed or careless visitors. Oily hands discolor and irreparably damage pictographs and petroglyphs, and campers and campfires inside rock shelters destroy fragile stratigraphy. Artifact collectors walk away with evidence of prehistoric cultures.

Quite simply, many places on the plateau are being "loved to death." Land managing agencies are taking proactive approaches to protect the fragile natural and cultural resources. These measures include guided tours, fenced archaeological sites, "hardening" sites for visitation by intensely recording them and stabilizing their structures, and trails and signs. With reduced staffing and limited federal funding, agencies increasingly rely upon

interagency collaboration, partnerships with local governments and organizations, and a network of volunteers. Education efforts are under way, too, to make the American public aware of the issues concerning their public lands and help them understand how to tread lightly when visiting their national treasures.

## Water

In an arid region, water is a focal point for humans, wildlife, plants, and all other life-forms. Indeed, many of the problems on the Colorado Plateau have water at the nub of the controversy. Issues surrounding use of the Colorado River, one of the nation's great rivers and the main artery of the Colorado Plateau, are well known and longstanding. The river runs through seven U.S. states and Mexico, serving nearly 25 million people, so there are many competing demands. However, even the smallest trickle of water on the plateau is an oasis and a potential point of conflict.

Most of the plateau's animal life (80 percent, by some estimates) and much of its plant life depend upon the thousands of kilometers of tiny streams and small rivers that ultimately feed the Colorado River. The riparian areas, or green strips, that run alongside the streams and rivers are a focus of management concern. Located in the narrow band between the water's edge and dry upland landscapes, these areas provide critical wildlife habitat. The condition of riparian systems affects the health of the entire ecosystem.

In the Colorado Plateau, degradation of riparian areas has resulted from historic grazing activities and other factors, including recreation impacts along heavily used trails, off-highway vehicle traffic, dam building and stream channeling, and groundwater withdrawals from wells. The vagaries of western water law exacerbate riparian problems. To exercise water rights, users are given incentives to consume, not conserve, water. The water needs of wildlife, vegetation, and riparian systems are shortchanged.

Invasive exotic plants, especially *Tamarisk sp.* (salt cedar) are a major problem in riparian areas; they out-compete native vegetation and overrun habitat for birds and animals. Tamarisk absorbs large quantities of water, making surface water unavailable to wildlife and other riparian plant species. Once established, the effects of this shrub-tree can be insidious. In addition to increasing soil salinity, tamarisk increases fire frequency. The large masses of dead leaves and branches produced by the fast-growing



Named for the hunchbacked flute player of Native American culture, Kokopelli's Trail offers mountain bikers 225 km of roads that climb to 2,800 m.

BRAD FRANK, BLM

tamarisk provide ample fuel for wildfires. After fires, tamarisk plants typically sprout vigorously, out-competing the slower-growing native riparian trees and shrubs.

While tamarisk is a particular problem in riparian areas, invasive plants are also a serious problem elsewhere on the plateau. The primary avenues for the dispersal of weeds are transportation corridors, including trails. Vehicles, as well as people and animals using these travel corridors, act as vectors for the spread of these weeds to previously unaffected areas.

Numerous approaches are being taken to tackle the invasive plant problem. Policies and guidelines for control of these noxious weeds have been developed. Weed-free hay certification has become a standard policy in many areas.

Although recovery from riparian area impacts is slow and in some cases may never occur, western land managers have committed to making restoration a priority. As a first step, they are conducting assessments on riparian areas to analyze the areas' capability and potential. Specialists examine vegetation, landforms, soils, and hydrology to determine whether an area is functioning properly, at risk, or non-functional. Ratings help land managers set priorities for where restoration projects and changes in management practices are most needed. Riparian area health requires a broad-based effort, with public land managers working closely with local communities.

Dams bring different kinds of changes to riparian ecosystems. All of the major rivers that flow through the plateau have been dammed, and with similar effects. The Glen Canyon Dam holds back the Colorado River and forms Lake Powell, 300 km in length. A popular recreation area, Lake Powell and the Glen Canyon

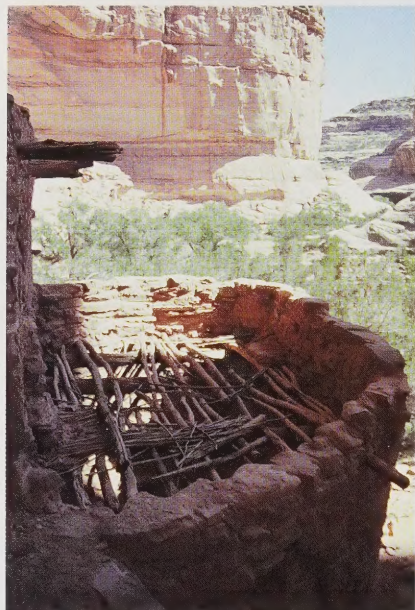


The Colorado Plateau's many canyons provide rafting enthusiasts with both heart-stopping whitewater and wildlife-watching opportunities.

Dam also provide hydroelectric power, water storage, and flood control. However, the effects on the Colorado River ecosystem have been dramatic. Before construction of the dam, the river was a warm, muddy flow with tremendous seasonal fluctuations. Once dammed, the river immediately became a clear flow of cold water, drawn from deep in the reservoir behind the dam and with a much different fluctuation pattern. The sudden change to cold, clear water had a major impact on the warm-water native fish of the Colorado River. The effects of the dam have not all been negative; other, nonnative coldwater species—primarily rainbow, brown, and cutthroat trout—have thrived. In fact, the Glen Canyon stretch from Lees Ferry to the dam has become a renowned trout fishery.

Since construction of the Glen Canyon Dam, the sandbar beaches along the river have been shrinking; in the past,

silty floods seasonally renewed these features. The absence of the seasonal high, dirty flows has been a boon for much of the plant life in the canyons, which grows much closer to the water than it could in the past. The bad news is that the exotic tamarisk now dominates the beach-plant community, undermining its diversity. These shallow-rooted plants do



SHELLEY SMITH

*A well-preserved cliff dwelling in southeastern Utah, about 1,000 years old.*

not hold the beaches and sandbars against persistent erosion.

In 1996, an experiment was conducted to test a hypothesis that a sustained "floodflow" might stir up the sand and silt from the bottom of the main channel and redeposit it onto the bars and beaches. Restoring these features would reestablish backwater breeding pools needed by the endangered native fishes; replenish the camping beaches; and water the mesquite, acacia, and other native vegetation in the high-water zone. The gates of Glen Canyon Dam were opened and the test "flood" began. It remains to be seen how stable the new-formed deposits are, although preliminary results are encouraging.

## Minerals

The Colorado Plateau contains important mineral resources, including oil and gas, coal, metals, gypsum, stone, and gravel. Exploring for and extracting these resources present a difficult situation. For example, where coal is strip-mined, there is considerable surface disturbance. Because revegetation is a critical compo-

nent of reclamation when this type of large-scale disruption has occurred, the arid environment and slow-growing vegetation of the plateau make the task daunting. Oil and gas development causes minimal damage to the landscape, but does present problems, primarily in the form of visual intrusions and the loss of wildlife habitat. The pits associated with oil and gas development often contain oil and other dangerous substances that are hazardous to wildlife that land in or drink from them. Birds fall victim to the well separators. Fenced wells and areas that require protection as well as above-ground pipelines can affect deer herds.

Some of the mining-related problems here are really the legacy of past activity. For example, the search for uranium and vanadium that began in the late 1800s on the Colorado Plateau has left behind tailings and abandoned mines. Tailings, the leftovers from mining and milling, contain radioactive and other hazardous materials.

Many abandoned mines are on public lands that have only recently come under federal management. The location and nature of early mining activities on these lands are often poorly documented. Federal agencies are conducting efforts to locate and reclaim historic mine sites that pose public safety risks or environmental threats.

Even mines that have been located and properly abandoned are sometimes vandalized, entered, and left open, potentially exposing others to unexpected risks.

However, these mines are beneficial to the ecosystem in at least one way. Many of North America's largest remaining bat populations now roost in mines, which often provide microclimates similar to caves. Two species in particular, Allen's big-eared and Townsend's big-eared bats, are closely tied to abandoned Colorado Plateau mines. Mines are key sites for rearing young in summer, hibernating in winter, and using as temporary havens. They can also serve as crucial migratory rest stops in the spring and fall. Bat-accessible mine closure gates support bat populations, which in turn reduce other problems. Bats are the primary predators of night-flying insects, many of which attack agricultural products and forests. For example, a single little brown bat can catch 600 mosquito-sized insects per hour. A colony of Mexican free-tailed bats living in the old Orient Mine in Colorado consumes nearly two tons of insects nightly.

## Native Americans

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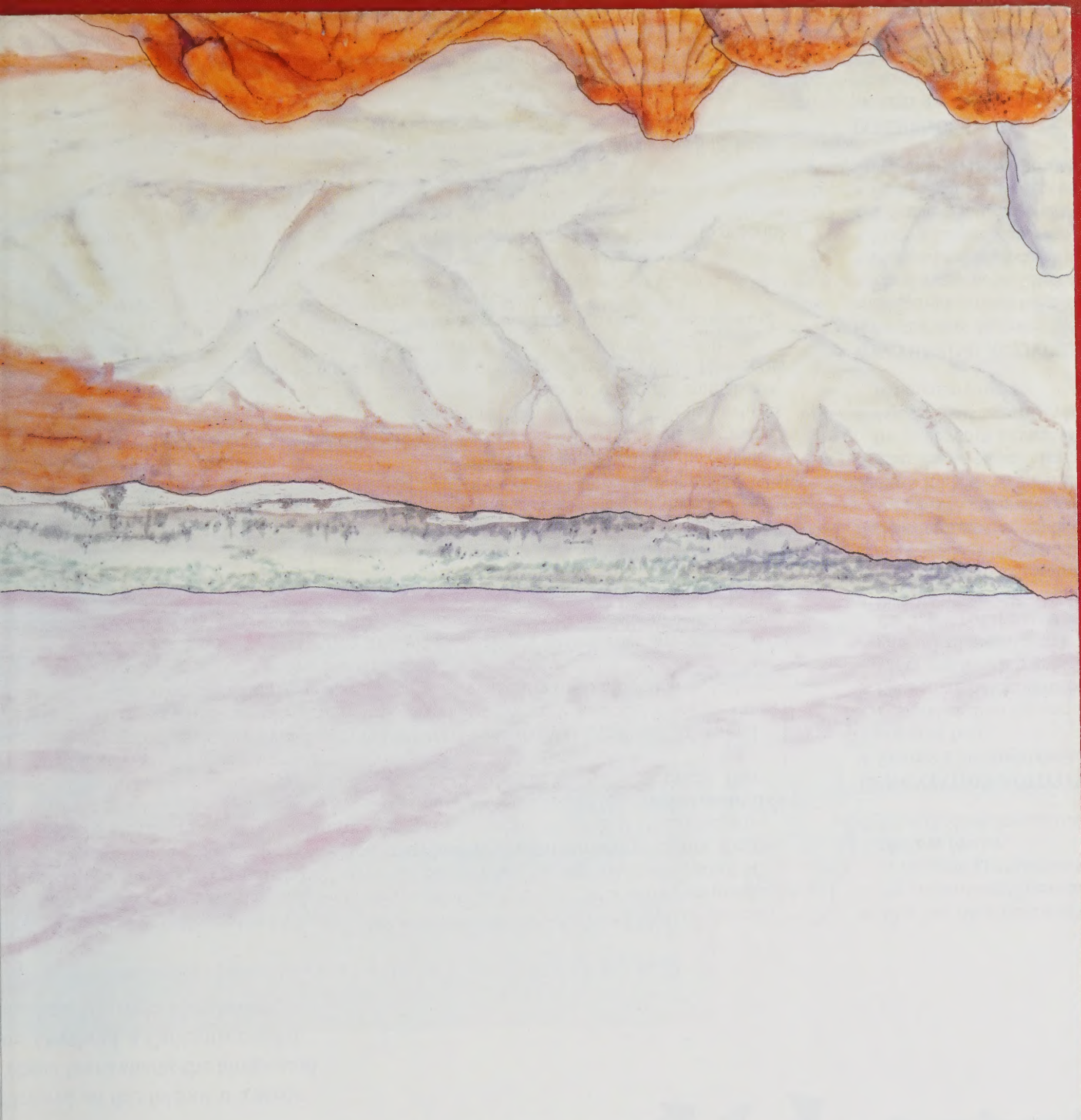
have long been residents of the Colorado Plateau. The Navajo Nation, the largest tribe, is centered in northeastern Arizona, with holdings in northwestern New Mexico and southeastern Utah (see the back of the accompanying foldout). Many Indian people live in two worlds, participating in modern American society and maintaining traditional beliefs and practices. Historically relegated to reservations, tribal people once called vast areas home, and today sites and resources that are significant to them are located on off-reservation lands. Energy resources (oil, gas, and coal) that are owned by tribes but managed by other agencies are of concern to tribal governments. Tribal governments and land-managing agencies are working more closely to coordinate management practices that affect sacred sites or areas where Native Americans traditionally gathered plant foods and materials.

## Developing a Vision

The residents, land managers, and special interests grappling with the future of the Colorado Plateau face a special problem, because this region has no single unifying structure to address its collective issues. Though the lands of the plateau comprise the backyard of four states and are of interest to others for their potential recreational and economic contributions, the plateau is not the responsibility nor the principal interest of any state or regional governing organization.

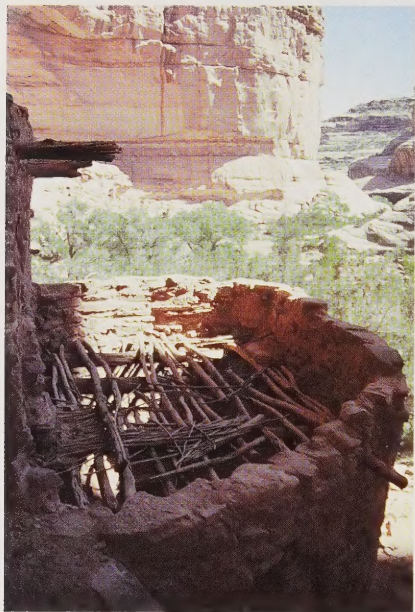
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Spectacular and unique, the Colorado Plateau demands our best efforts to conserve its resources. Its magnificent rock formations, spectacular vistas, archaeological sites, and varied plant and animal life are like no other on Earth. The opportunity to appreciate its beauty and resources is a valuable legacy to present and future generations.



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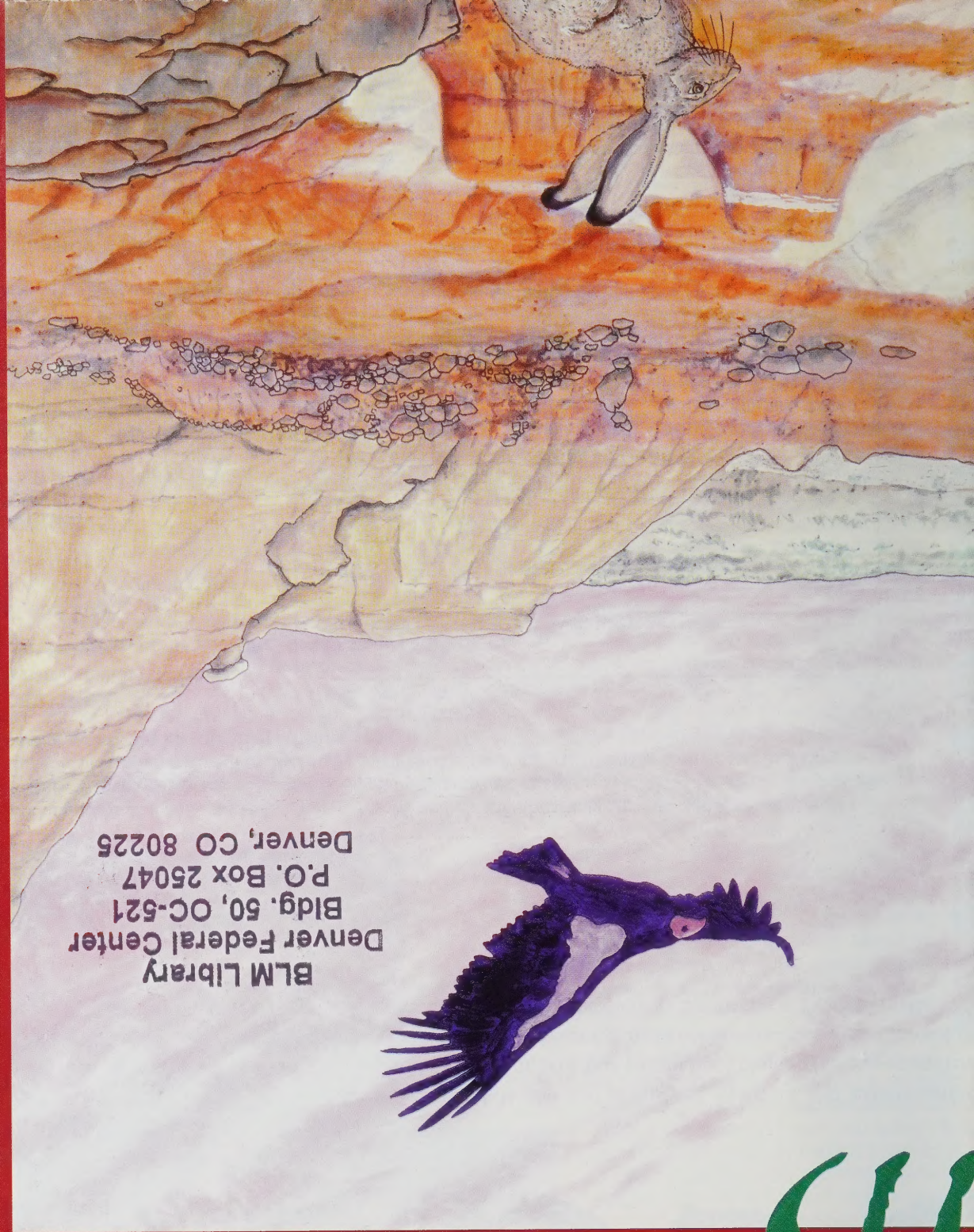
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# The Colorado Plateau Ecosystem

## HOODOOS & Horizons



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## Life in the Desert

**Background:** Terrestrial animals in the desert exhibit a number of different strategies to cope with scarce and unpredictable water sources. Some forage at night, when lower temperatures reduce the amount of water the animals' bodies need for cooling. Some other mechanisms are gathering early morning dew and excreting small amounts of very concentrated urine.

**Question:** What strategies do terrestrial animals, which depend upon limited or temporary water supplies, need to survive?

**Materials:** You will need small sponges, water, a balance scale, and descriptions of desert plants and animals.

**Procedure:** 1. Provide students, working individually or in small groups, with a small sponge saturated with water. Explain to them that this represents a desert animal with a limited amount of available water. Over a 24-hour period, students should take care of their "animal" in a manner that will best conserve the water it contains, using only natural materials. Their "animal" must be in the open for at least four hours during that time to "feed."

2. To measure the beginning moisture content, each student or group should use the balance to determine the mass of its sponge. A control sponge should be left unprotected for the experiment's duration. Students should then plan a strategy and write it down along with predictions of what will happen.

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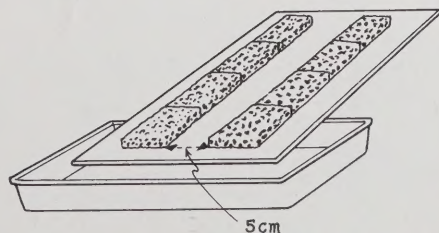
## Life in a Pothole

**Background:** Potholes are populated by a variety of organisms. The ways that these creatures come to occupy a particular pothole are different from how most other niches in an ecosystem come to be occupied. Insects, toads, and birds can use their mobility to select potholes. There is some preliminary evidence that at least the female toad returns to the pothole from which she hatched. During periods of heavy rainfall, some potholes could overflow into lower potholes, washing organisms along with the water. This is probably not very common, since most potholes are not in a downstream relationship with one another, and population inventories show a widely scattered, almost random pattern of species presence or absence. Birds may help populate potholes with organisms such as snails that could cling to their feet and be transported to the next water body the bird visits. Desiccated shrimp eggs and mites are almost identical in dimension to sediment grains, which, when dry, are blown about by the wind. The eggs and mites would be transported along with sediments. Wind distribution is consistent with the random population pattern.

**Question:** How do various life-forms come to populate widespread potholes?

**Procedure:** After sharing information about pothole life (see main article) with students, ask them to predict how the various life-forms in potholes came to be there.

**Extension:** Create a classroom pothole. Brine shrimp and tadpole shrimp eggs (Triops) are sold in pet stores as fish food. They can be raised under different environmental conditions, such as different temperatures, (within limits), and on various food sources (e.g., alfalfa-based, dried brine shrimp or tubifex worms, fish foods). Record population changes under the different regimes.



## Riparian Activity

**Background:** This activity lets students demonstrate the greater water-retention capacity of a meandering stream. Where the natural gradient is not steep, healthy streams generally have numerous meanders. Water slowly moves along, allowing it to soak deep into the banks, which act like giant sponges. They release water during periods of low waterflow, providing a buffer to the riparian-dependent plants and animals.

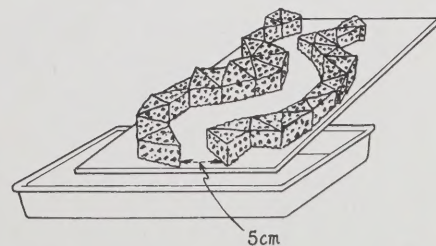
**Question:** How do the water-retention capabilities of meandering and channelized (straightened) riparian systems compare?

**Materials:** You will need a measuring cup, several flat-bottomed sponges, a cookie sheet, and a pan wide enough to accommodate the width of the cookie sheet.

**Procedure:** 1. First, simulate a channelized riparian area by laying dry sponges end to end in two rows the length of the cookie sheet, with about 5 cm of space between the rows (see diagram below). Place the end of the cookie sheet in the pan, and hold the opposite end at a low angle. (Don't let the cookie sheet rest on the edge of a pan if the angle of the cookie sheet will be steep.)

2. Gradually pour 240 mL of water down the trough between the sponge rows. Some water should seep into the sponges, but most should wash into the pan. Measure how much water is in the pan.

3. Now, simulate a healthy meandering riparian system by laying pre-trimmed dry sponges in two parallel rows, but this time arrange them in a series of several curves. (Cut and piece wedges of sponge beforehand to create solid banks, see diagram below.) Again, gradually pour 240 mL of water down the trough and measure the amount that makes it to the pan. This time, there should be much less water in the pan because the meandering riparian system has soaked up water into its banks. You can further experiment with the angle of the cookie sheet to simulate the effects of different stream gradients.



# HOO DOOS & Horizons

Somewhere in the distance, a coyote howls, as might be expected in this vast, beautiful, and austere landscape. Pictured on this foldout is a scene from the Grande Staircase-Escalante National monument, which is part of the Colorado Plateau ecosystem. A collared lizard shares the foreground with Kayenta pottery, while a black-tailed jackrabbit and a towering toadstool hoodoo rock formation set the scene. Overhead, a California condor, newly released into the area, soars on the air currents. And somewhere in the distance, a coyote makes his way amongst the rocks and shrubs.

## ACTIVITY 1

### Make Your Own Field Guide!

Working in small teams, students observe, record, and identify the wildlife, plants, and geology of their area. They then classify their data and collaboratively prepare a customized local field guide. In the process, students determine factors that need to be considered concerning the adequacy of their data and the purpose of a particular classification scheme.

#### DURATION

Variable; minimum of three class periods.

#### CLASS SIZE

Any; students work in teams of three to five.

#### MATERIALS

You will need

- cameras and film or drawing materials,
- reference books,
- and field guides.

#### BACKGROUND

Science begins with observation, whether through a microscope or a telescope. Physicists, astronomers, archaeologists, botanists, biologists, and geologists—all scientists—must identify the data they are observing. Land managers, too, must start with a knowledge of the living and nonliving components of the ecosystem they are managing. They rely on staff specialists to provide inventories of plant and animal species and geologic formations. Specialists refer to technical publications and field guides to help identify specimens with which they are unfamiliar. Sometimes a particular specimen will not be included in a reference, either because it is unusual and the reference is not exhaustive, or because the reference does not really fit the geographical area of the specimen's origin. In rare instances, the specimen is a discovery of a heretofore unknown species or formation.

Students can make their own field guide tailored to their local area. The field guide can focus on just plants or animals or insects or rocks, or it can be a compilation of several ecosystem components. The process of preparing a field guide gives students experience in observation, recording, research, classification, art or photography, data evaluation, and teamwork. The resultant field guide can be filed in the school library. It can also be reproduced and distributed as an activity extension.

#### SETTING THE STAGE

Ask students what they would do if they saw an unusual animal, plant, or rock in their neighborhood. Alternatively, show them a picture or drawing of a plant, animal, or rock that they are unlikely to recognize. Ask how they would learn more about it. Guide the discussion to help students realize that before they can do anything else, they need to identify the specimen. Question students as to how they would identify the animal, plant, or rock. After discussing various kinds of resources (technical publications, field guides, and specialists), tell students that they are going to prepare, as a class, a field guide specially customized for their local area.

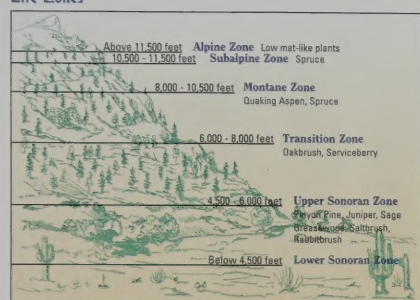
#### PROCEDURE

1. Define the scope of the field guide project. Decide, either beforehand or as a class, the geographical and topical scope of the field guide. You may decide to just concentrate on plants or trees, for example. Or you may decide to include reptiles, insects, fish, historic sites, or other components of the ecosystem. Define the geographical scope by realistically assessing the number and duration of field excursions that will be possible. You also need to decide whether to focus on only wilder, natural areas or, especially in urban environments, to include introduced species and landscaped areas like parks.

2. Prepare the class for the activity. Explain the importance of good notes and accurate observations. Demonstrate the procedure the students will use by taking them outside to observe a plant or tree. Have students write a description and draw or photograph it. Collect a leaf or other diagnostic plant part, such as a flower or leafed stem. For small plants, collect the whole specimen, including roots. Assume that there are at least 20 individual plants nearby and that none are endangered or poisonous. Once back in the classroom, use field guides and technical references to identify the plant. Have students label their drawings with both the Latin and common names. Alternatively, a specialist from a land-managing agency (Bureau of Land Management, U.S. Forest Service, National Park Service), local university botany department, or natural history museum can visit the class and demonstrate the procedure, perhaps bringing along herbarium reference specimens.

3. Divide the class into groups of three to five students. Assign each group a topic, such as trees, grasses, flowers, insects, mammals, and so on. You could also assign topics geographically, having each group visit a different nearby natural area. Another option is to have students individually record observations in their neighborhood. If you have the chance to take a field trip, have a parent volunteer work with each group.

#### Life Zones



Life zones and Colorado ecosystems maps from Exploring Colorado: A Naturalist's Notebook by Frances Alley Kruger and Camp A. Moore, published by the Denver Museum of Natural History and Westcliffe Publishers. ©1985 by the Denver Museum of Natural History, used by permission.

4. Conduct field work. Parent volunteers can escort individual teams on their own field trips, or you can arrange for one or more class field trips with volunteers assisting each group. Set a minimum number of data entries for each group. The team members may want to specialize, having one student scout for animals, one for birds, one for plants, etc., depending upon how you've structured the activity. If cameras are available, team members should take turns taking and recording the photos. Otherwise, students should draw or collect the specimens. In any case, students should record information about their data entries, including location, date, recorder, and other data that they or you feel is pertinent. There should be no duplicate entries within a group.
5. Once back in the classroom, students should identify their specimens. They can use field guides and technical publications, visit a natural history museum or herbarium, or ask a specialist. Give the students guidance on what information to record about each specimen: Latin or common name, historic and prehistoric uses, seasonality, place in the food web, etc.
6. Compile the class field guide. As a class, decide how the field guide should be formatted and organized (by kind of area, such as ponds, grasslands, and forests; by plant, animal, and rock; by color of flower, etc.). Discuss classification systems and the purposes for which they are constructed. Depending upon the use to which they will be put, classification systems are more or less effective, not right or wrong. Decide what roles students will have in assembling the field guide: writers, illustrators, index-makers, word-processors, etc. After each student has completed his or her assigned piece, assemble the field guide.
7. Test the field guide. If possible, take the class to a new area and use the field guide to identify the ecosystem components there, or ask another class to try to use the field guide. Critique the field guide. Is it usable? What improvements could be made? Even if it is not possible to actually use the field guide, conduct the critique.
8. Discuss the field guide's limitations. Limitations could include the fact that invariably some specimens will be left out. What are the reasons for incompleteness? Brainstorm ideas, but be sure the list includes time and money constraints, the fact that some animals and plants are seasonal, nocturnal animals are not represented, and some specimens may be buried in tree trunks, or otherwise unobservable. How could these limitations be overcome? Is it even necessary to have an exhaustive field guide? Connect these points to the practice of science in general, and to the fact that all science has limitations. Recognizing and evaluating these limitations is an important part of the scientific process.

#### EVALUATION

Evaluate learning by the quality of the field guide contribution from each student. Ask students to describe how the project is an example of the first stages of the scientific process.

#### CLOSURE

Share the field guide with others through a display at the school, public library, mall, or public building. Invite a local newspaper or radio station to feature the project and have students describe their work as scientists.

#### EXTENSIONS

- Prepare herbarium specimens of plants by pressing them and gluing to heavy paper labeled with the common and scientific names.
- Seek publication or duplication of the guide through donations from local printers.
- Follow the lead of the Tope Elementary School and Diane Hirschinger Gallegos, and prepare a field guide for others to use. Through 25 field trips, over 3,000 photos, and 500 pages of student writing, *Through the Eyes of the Children: A Field Guide to Western Colorado and the Colorado Plateau* was prepared. A teacher pre-scouted a route and placed markers at significant features. Each group of four students was escorted on a field trip by a parent volunteer who had a list and description of the features to record. A local photographic shop donated disposable cameras and instructed students on how to take good pictures. The group then photographed the teacher-identified features and discovered numerous other specimens to record on their own. The field guide was developed in answer to the frustrations of students trying to identify animals, plants, and rocks through technical publications and field guides that covered broad regions. It is organized in a readily accessible way and the schoolchildren use it regularly to identify what they see around them. For more information, or to purchase *Through the Eyes of the Children* (\$14.95), contact Diane Gallegos at (970) 243-1565 or Tope Elementary School at (970) 242-0433.

## ACTIVITY 2

### Deposition, Lithification, and Weathering of Sedimentary Rock

#### QUESTION

Most of the rocks exposed at the Earth's surface—more than 70 percent, in fact—are sedimentary rocks, composed of deposits of sand, silt, or clay, often sorted into neat, homogeneous layers. But how are loose, mixed-up sediments actually transformed into the massive, layered accumulations of rock we see in the Colorado Plateau?

After sediments are deposited, the processes of compaction and cementation cause grains, granules, and particles to form rock, or lithify. In the plateau, sediments were compressed under their own great weight and then cemented by dissolved substances, such as calcium carbonate, to form sedimentary rock. Erosional forces, such as water and wind, constantly work to wear down rock, creating loose sediments that may one day form new rock. The following activity illustrates the processes of deposition, sorting, cementation, and weathering.

#### MATERIALS

- For this activity, you will need
- sand (300 mL per student group);
  - gravel (90 mL per student group);
  - water;
  - 1 L jars with lids (one per group);
  - nontoxic white glue;
  - 150–210 mL paper cups (two per group);
  - small-diameter ring stands (one per group);
  - and small bowls (one per group).

#### DEPOSITION/SORTING ACTIVITY

1. Give each group a jar approximately half-filled with water. Also give each group two separate quantities—120 mL and 60 mL—of a 50:50 sand/gravel mixture.
2. Instruct the students to add 120 mL of the mixture to the jar, place the lid on the jar, shake it, and then let it stand for 10 minutes.
3. During this waiting time, have the students predict how the sediments will settle.

4. After the 10-minute waiting period, have the students add the remaining 60 mL of the sand/gravel mixture *without shaking the jar*.
5. Have students record their observations.

#### CEMENTATION ACTIVITY

1. Prepare a 50:50 glue/water mixture ahead of time.
2. Position each ring stand above a bowl.
3. Poke small holes in the bottom of one paper cup for each group, so that the glue mixture will be able to pass through the holes, but the sand will not.
4. Fill one of the perforated cups with sand for each group and distribute.
5. Have students suspend the cup in the ring stand above the bowl.
6. Distribute a paper cup full of glue mixture to each group. Direct the students to gradually pour the glue solution into the sand-filled cup.
7. Allow the glue to drain through the sand for several days.
8. After the glued sand has dried, direct the students to tear away the paper cups to view their "rocks."
9. Ask students to explain how their sand blocks are similar to sedimentary rocks.

#### WEATHERING ACTIVITIES

- Have students describe changes in their "sandstone" after it is subjected to various forms of artificial weathering:
- Place a sample in a sink and allow tap water to drip on it overnight.
  - Place a sample under direct lamplight for two weeks.
  - Place a sample in a freezer for a month.
  - Alternate a sample between the lamp and freezer (weekly for a month).
  - Place a sample outside where it will be exposed to natural weather conditions and make weekly observations during the semester.

#### INFERENCES

Though the time frames of these activities are infinitely compressed relative to those of natural geologic processes, students will nevertheless gain a hands-on understanding of the mechanisms that transform loose sediments into sedimentary rock and back into loose sediments again.

### Nature's Sculptors: Water, Wind, and Ice

#### Arch

Arches begin to develop when water seeps into vertical cracks in sedimentary rock. Winter ice forms in these fissures, putting pressure on surrounding rock and breaking off pieces that are then scoured out by wind. Eventually, this process results in a series of narrow, freestanding landforms. Wind and rainwater continue to attack these "fins" until big chunks tumble out, leaving holes and sometimes causing collapse. If a fin has the right degree of hardness and balance, however, it may survive rock loss and remain standing. Further weathering enlarges the holes; fins with holes that grow to at least 90 cm in diameter are considered true arches.

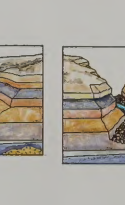
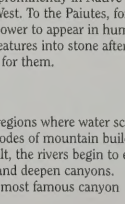
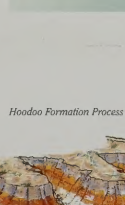
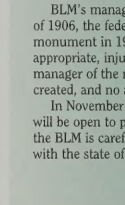
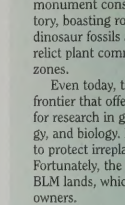
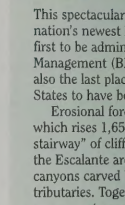
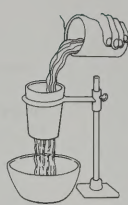
#### Hoodoo

Hoodoos typically form along sedimentary plateau rims, where steep slopes result in high-energy water runoff along faults and joints. Freeze-and-thaw weathering loosens slope surfaces, whose debris is washed away by runoff, scouring and gullying softer rock as it runs through. Progressive gully erosion sculpts isolated fins of rock that undergo cracking and peeling of layers, eventually resulting in columnar hoodoos. A hard caprock, generally a boulder or cobble, protects the column of softer sediments beneath it. Hoodoos may be a few centimeters to many meters high.

Because of their strange shapes, hoodoos figure prominently in Native American lore on the Colorado Plateau and elsewhere in the West. To the Paiutes, for example, they are the petrified remains of animals that once had the power to appear in human form. According to legend, the trickster-hero Coyote turned the creatures into stone after they refused his invitation to live in a cliffside village he had built for them.

#### Canyon

Canyons are deep, steep-sided river valleys that form in dry regions where water scarcity limits erosion from runoff. When land is uplifted during episodes of mountain building, river gradients on adjacent flat areas are steepened. As a result, the rivers begin to erode deeply into the plain. Wind erosion and fault movement help to widen and deepen canyons. The Grand Canyon, at 1.6 km deep and 445 km long, is the largest and most famous canyon in the world, though worldwide, several canyons are much deeper.



## Life in the Desert

**Background:** Terrestrial animals in the desert exhibit a number of different strategies to cope with scarce and unpredictable water sources. Some forage at night, when lower temperatures reduce the amount of water the animals' bodies need for cooling. Some other mechanisms are gathering early morning dew and excreting small amounts of very concentrated urine.

**Question:** What strategies do terrestrial animals, which depend upon limited or temporary water supplies, need to survive?

**Materials:** You will need small sponges, water, a balance scale, and descriptions of desert plants and animals.

**Procedure:** 1. Provide students, working individually or in small groups, with a small sponge saturated with water. Explain to them that this represents a desert animal with a limited amount of available water. Over a 24-hour period, students should take care of their "animal" in a manner that will best conserve the water it contains, using only natural materials. Their "animal" must be in the open for at least four hours during that time to "feed."

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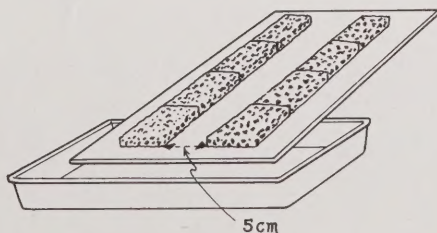
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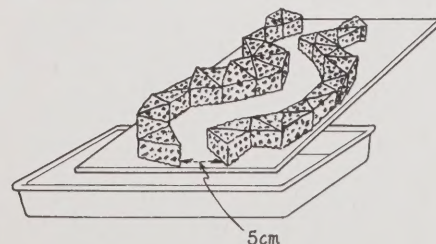
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## Teacher Resources

### Web Sites

- Bureau of Land Management, Anasazi Heritage Center (information on Ancestral Puebloan culture), <http://www.co.blm.gov/ahc/hmepage.htm>
- Mesa Verde County (CO), Anasazi Archaeology (information on Ancestral Puebloan culture in southwest Colorado), <http://www.swcolo.org/Tourism/ArchaeologyHome.html>
- Canyonlands Field Institute (outdoor environmental educational programs for children and adults on geology, ecology, and issues facing the Colorado Plateau), <http://www.canyonlandsfieldinst.org>
- National Biological Survey (tribes of the Colorado Plateau), <http://www.nbs.nau.edu/Tribes>
- Grand Canyon Field Institute (outdoor and classroom programs to enhance understanding of the Grand Canyon region's natural and cultural history), <http://www.thecanyon.com/fieldinstitute>

### Software and Other Resources

- *People in the Past: The Ancient Pueblo Farmers of Southwest Colorado*. [CD-ROM and classroom activities]. Southwest Natural and Cultural Heritage Association, Albuquerque, NM, and Department of the Interior, Bureau of Land Management, Anasazi Heritage Center, Dolores, CO. Available through the Anasazi Heritage Center Museum Shop, (970) 882-4811, ext. 111; or e-mail [tpainter@co.blm.gov](mailto:tpainter@co.blm.gov).
- *Intrigue of the Past: A Teacher's Guide for Fourth through Seventh Grades*. Bureau of Land Management, Anasazi Heritage Center, Dolores, CO. For information on the teacher's guide, state-specific supplements (including the Colorado Plateau states), and teacher workshops, contact the Anasazi Heritage Center at (970) 882-4811; or Web page <http://www.co.blm.gov/ahc/projectarch.htm>.
- The Anasazi Heritage Center, Department of the Interior, Bureau of Land Management, Dolores, CO, has a library containing books, magazines, and videos about the archaeology, history, and cultures of the Colorado Plateau. All resources may be checked out free of charge and can be mailed anywhere. For information, call (970) 882-4811; e-mail [meastin@co.blm.gov](mailto:meastin@co.blm.gov); or visit the Web site at <http://www.co.blm.gov/ahc/hmepage.htm>.

- *History of Indian Peoples of the Four Corners Area*. [laserdisc]. Department of the Interior, Bureau of Land Management, Santa Fe, NM.
- *Excavations at Ladle House, an Anasazi Pueblo*. [CD-ROM]. Woods Canyon Archaeological Consultants, Yellow Jacket, CO.

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### About the Authors

Bibi Booth, Shelly Fischman, and Shelley Smith are Bureau of Land Management (BLM) education specialists, Richard Brook is a BLM archaeologist, LouAnn Jacobson is director of the Anasazi Heritage Center, and Mary Tisdale is the national program manager for BLM environmental education and volunteer programs.

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